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POST-BIRTH DEVELOPMENT OF *VAEJOVIS BILINEATUS* POCOCK (SCORPIONES: VAEJOVIDAE)

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ABSTRACT

The post-birth development of *Vaejovis bilineatus* Pocock was studied in the laboratory. Litter size varied from 17 to 26 among five litters reared. The average growth factor between successive molts for carapace length was 1.26 ± 0.05; for chela length 1.28 ± 0.05; and for metasomal segment V length 1.32 ± 0.07. Although no specimens were reared from birth to maturity, it was determined by extrapolation and comparison with field-collected adults that there are six instars (five molts) to maturity.

INTRODUCTION

Only two studies dealing with post-birth development of the Vaejovidae have been published to date. Francke (1977) reared *Uroctous mordax* Thorell in the laboratory, but only one male successfully reached the fifth instar. From its size at that age, Francke estimated that maturity was reached at the seventh instar. Polis and Farley (1979) conducted field studies on *Paruroctonus mesaensis* Stahnke. They reported that (1) maturity was reached at 19 to 24 months of age, (2) there were seven instars in the post-birth development, and (3) growth was determinate. In addition they discussed ecological parameters affecting the life history of *P. mesaensis* and presented a summary of all published scorpion life histories in tabular form.

In addition to these studies, there have been several others of related interest. McAlister (1960) discussed growth rates of first instar young of *Vaejovis spinigerus* (Wood). Williams (1969) published information on birth behavior for *Anuroctonus phaiodactylus* (Wood), *Uroctonus mordax* Thorell, *Vaejovis confusus* Stahnke, *V. minimus* Kraepelin, *V. spinigerus*, *V. vorhiesi* Stahnke, and *P. mesaensis*. He also included descriptions of first and second instars of those species. Haradon (1972) published additional information on birth behavior for *U. mordax*. Finally, Hjelle (1974) published observations on the birth and post-birth behaviors of *Syntropis macrura* Kraepelin.

The present study represents the first developmental information available for the genus *Vaejovis* beyond the second instar. Five pregnant females of *Vaejovis bilineatus* Pocock were collected at Villa Hidalgo, San Luis Potosí, México in March 1977. They gave birth in the laboratory in August and their litters (n = 17, 20, 22, 25, and 26) were

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reared. As the litter of one female (n = 17) died as second instars, the specimens were omitted from all calculations. Fourteen specimens from the other litters entered the fourth instar and one of those entered the fifth. An immature female collected with the adults at Villa Hidalgo molted twice and reached maturity in the laboratory. The specimens from these two sources provided a complete study of the post-birth development of *V. bilineatus.*

MATERIALS AND METHODS

Rearing methods used in this study have been described elsewhere (Francke 1977, 1979). Briefly, young scorpions born in the laboratory were separated into individual containers as soon as the litters dispersed from the females' dorsa. A layer of soil was provided as a substrate, and water was provided with a moistened sponge. Early instars were fed macerated bits of roaches (*Nauphoeta cinerea* Saussure), as available living prey were too large for the young scorpions to subdue. The later instars were given live immature *N. cinerea*. All specimens were maintained in an environmental chamber at near constant temperature (26.6 ± 2°C).

Two problems resulted in loss of specimens and/or data. The macerated bits of roaches used as food molded rapidly and young scorpions became trapped in the fungal hyphae. The specimens were killed and usually damaged as a result. Other specimens died after burrowing in the soil and dessicated so that measurements were useless.

Measurements of carapace length, pedipalp chela length, and metasomal segment V length were taken for all instars observed (either from exuviae or preserved specimens). All measurements were taken with an American Optical Model 569 binocular dissecting microscope equipped with an ocular micrometer calibrated at 20X.

Growth factors between successive instars were calculated from the data by dividing the dimension of a structure at one instar by its dimension at the previous instar. An average growth factor and the standard deviation were calculated for each molt from the pooled data. In the text and tables, all average ages, measurements, and growth factors are accompanied by the standard deviation (in the form of $\bar{x} \pm s$) unless otherwise specified.

The failure of specimens to reach maturity required the use of extrapolation and calculation of 95% confidence intervals of instars not observed in the litters (see Francke 1979 for procedure). Measurements of field-collected adults from the same or nearby localities were compared to predicted size ranges of instars, and the instar at which maturity is reached was thus inferred.

RESULTS

First Instar.—The young of *Vaejovis bilineatus* are born enclosed by a "birth membrane" as are other apoikogenous scorpions (Francke, in press). Upon freeing themselves from this membrane the young climb onto the mother's dorsum and orient themselves in rows with the prosoma directed forward and the metasoma backward. This layering effect was reported by Williams (1969) for several *Vaejovis* spp. and is apparently characteristic of the genus. We have observed the same for *V. coahuilae* Williams and *V. waueri* Gertsch and Soleglad.

The first molt occurred at an age of 9.78 ± 0.41 days. Molting of all the young took place in a single day. Dispersion of the young took two to four days to complete, and this process began at an age of 16.8 ± 1.7 days (7.0 ± 1.6 days after the first molt).

First instars of *V. bilineatus* are creamy white at birth and gradually darken until time of exuviation. As in all other scorpions studied to date, they lack many adult features.

Tarsi are blunt and lack claws; the aculeus is soft and blunt; trichobothria, setae, granulation, and carinae are absent; and the denticles on the margins of the pedipalp chela fingers are absent. Pectines, however, are well developed and contain the complete number of pectinal teeth.

Second Instar.–Laboratory mortality was very high in the second instar. Only 40 of 93 specimens (43.0%) survived this stage, and most of the deaths were probably due to dessication either prior to or during molting. There is good evidence for mortality from molting difficulties: specimens dying during or around peak molting periods had formed a new cuticle which was visible underneath the semi-transparent second-instar cuticle in the carapace region.

Specimens surviving the second instar (n = 40) molted to the third instar at an age of 106.2 ± 15.6 days. The duration of the second instar was 96.2 ± 15.7 days (range = 68-140 days) (Table 1). Measurements of second instar structures and growth factors for the second molt are found in Table 2. Growth factor information could be obtained for only 31 of the 40 specimens: seven specimens dessicated before measurements were taken and two died during the second molt (there was no cuticular expansion and hardening). The average growth factor from second to third instar in carapace length was 1.26 ± 0.06; in chela length 1.28 ± 0.05; and in metasoma V length 1.33 ± 0.07.

Second instars possess most of the adult characters. The body is covered with setae, and all trichobothria are present. The tarsi bear claws, the aculeus is hardened and sharp, and the dentate margins of the pedipalp chela fingers are developed. Coloration is essentially the same as in adults. Carinae of the pedipalps and metasoma are very poorly developed (carinal development is gradual throughout life).

Third Instar.–Of the 40 specimens reaching the third instar, only 14 (35%) completed it. Specimens surviving this instar molted to the fourth instar at an age of 190.1 ± 27.9 days. The duration of the third instar was 87.5 ± 20.4 days (range = 56-140 days) (Table 1). Measurements of third instar structures and growth factors for the third molt are found in Table 2. Only nine of 14 specimens yielded growth factor information: three specimens dessicated during the fourth instar (measurements were not possible) and two died during the third molt. The average growth factor from third to fourth instar in carapace length was 1.26 ± 0.04; in chela length 1.27 ± 0.04; and in metasoma V length 1.30 ± 0.04.

Fourth and Succeeding Instars.–All remaining young except one died during the fourth instar. The surviving specimen molted to the fifth instar at an age of 323 days; the duration of its fourth instar was 147 days (Table 1). Measurements of fourth and fifth instar structures are reported in Table 2.

One immature female was collected with the pregnant females at Villa Hidalgo; it molted twice in the laboratory and attained maturity. Growth factors for this specimen did not differ from the laboratory-reared litters (Table 2). The duration of its penultimate instar was 243 days. The specimen did not molt between January 1978 and its death in October 1981, so apparently there is no post-reproductive molt in this species. This is further evidence that post-reproductive molts do not occur in the Scorpiones.

Using methods described by Francke (1979), 95% confidence intervals were calculated for the fifth, sixth, seventh, and eighth instars. These confidence intervals were calculated from measurements and growth factors of fourth instar specimens (n = 9), rather than from the single fifth specimen. The confidence intervals for carapace length, chela length, and metasoma V length are found in Table 2.

Table 1.–Duration (Dur.) of instars and cumulative age (Cum.) at time of molting in days in laboratory-reared *Vaejovis bilineatus* Pocock. Only specimens surviving the second instar are shown. Deaths occuring during a given instar are indicated by "x". Specimens lost are indicated by "?". First instar means and standard deviations are based on all specimens from the four litters used (n = 93). The number in parentheses following the specimen number (Spec. No.) indicates to which litter the specimen belongs.

	First		Second		Third		Fourth	
Spec. No.	Dur.	Cum.	Dur.	Cum.	Dur.	Cum.	Dur.	Cum.
1(1)	10	10	131	141	098	239	x	
2(1)	10	10	100	110	093	203	x	
3(1)	10	10	100	110	x			
4(1)	10	10	086	096	x			
5(1)	10	10	089	099	?			
6(1)	10	10	105	115	081	196	x	
7(1)	10	10	086	096	x			
8(1)	10	10	095	105	x			
9(1)	10	10	073	083	x			
10(1)	10	10	089	099	x			
11(1)	10	10	088	098	090	188	x	
12(1)	10	10	098	108	x			
13(1)	10	10	080	090	x			
14(1)	10	10	100	110	109	219	?	
15(1)	10	10	068	078	072	150	x	
16(1)	10	10	098	108	x			
17(1)	10	10	101	111	x			
18(2)	9	9	093	102	140	242	x	
19(2)	9	9	118	127	x			
20(2)	9	9	083	092	101	193	?	
21(2)	9	9	118	127	x			
22(2)	9	9	090	099	x			
23(2)	9	9	090	099	056	155	x	
24(2)	9	9	123	132	x			
25(3)	10	10	105	115	x			
26(3)	10	10	092	102	x			
27(3)	10	10	094	104	076	180	x	
28(3)	10	10	072	082	x			
29(3)	10	10	096	106	x			
30(3)	10	10	102	112	x			
31(3)	10	10	094	104	072	176	147	323
32(4)	10	10	103	113	x			
33(4)	10	10	140	150	x			
34(4)	10	10	079	089	082	171	x	
35(4)	10	10	108	118	x			
36(4)	10	10	070	080	x			
37(4)	10	10	086	096	078	174	x	
38(4)	10	10	100	110	x			
39(4)	10	10	115	125	x			
40(4)	10	10	089	099	077	176	x	
n	93		40	40	14	14	1	1
x̄	9.78		96.2	106.2	87.5	190.1	147	323
s	0.41		15.7	15.6	20.4	27.9	–	–

Table 2.–Measurements in mm and growth factors of observed instars (mean ± standard deviation); predicted 95% confidence intervals for instars not observed in the laboratory; and measurements of field-collected specimens of *Vaejovis bilineatus* Pocock.
* denotes estimated instars of collected specimens.

	Carapace	Chela	Metasoma V
OBSERVED			
2nd instar (n = 88)	1.43 ± 0.07	1.61 ± 0.08	1.34 ± 0.09
Growth factor (n = 31)	1.26 ± 0.06	1.28 ± 0.05	1.33 ± 0.07
3rd instar (n = 31)	1.86 ± 0.13	2.09 ± 0.15	1.82 ± 0.17
Growth factor (n = 9)	1.26 ± 0.04	1.27 ± 0.04	1.30 ± 0.04
4th instar (n = 9)	2.30 ± 0.13	2.58 ± 0.18	2.30 ± 0.17
Growth factor (n = 1)	1.23	1.29	1.36
5th instar (n = 1)	2.74	3.30	2.89
Female molting in laboratory			
4th instar*	2.56	2.89	2.61
Growth factor	1.23	1.26	1.33
5th instar*	3.15	3.65	3.46
Growth factor	1.29	1.34	1.27
6th instar*	4.05	4.90	4.40
PREDICTED 95% CONFIDENCE INTERVALS			
5th instar	2.57 – 3.22	2.85 – 3.75	2.54 – 3.49
6th instar	3.23 – 4.06	3.65 – 4.80	3.30 – 4.54
7th instar	4.07 – 5.12	4.67 – 6.15	4.29 – 5.90
8th instar	5.13 – 6.45	5.98 – 7.87	5.57 – 7.66
FIELD-CAUGHT SPECIMENS			
Adult females (n = 9)	3.83 ± 0.39	4.62 ± 0.30	4.14 ± 0.26
Adult males (n = 2; range)	2.98 – 3.25	3.90 – 4.10	3.55 – 3.75
4th instar* (n = 2; range)	2.40 – 2.50	3.00	2.55 – 2.60
5th instar* (n = 2; range)	2.75 – 2.85	3.30 – 3.60	2.90 – 3.40

DISCUSSION

When measurements of field-collected adults are compared to the confidence intervals obtained from the laboratory-reared litters (Table 2, Fig. 1), most of them (73%) fit easily within the intervals predicted for the sixth instar. However, three adult females (two giving birth to laboratory-reared litters and the immature specimen molting twice in the laboratory) fall within the lower limits of the seventh instar. Although it is possible that these three females are indeed seventh instars, we consider them to be large sixth instar adults based on the following observations. The young of one litter are significantly larger than the others (Duncan's multiple range test; $\bar{x}$'s = 1.37, 1.41, 1.41, 1.42, 1.52; $p < 0.01$), and extrapolation from the average size of second instars (using the growth factor obtained from this litter) shows that a specimen of this litter could easily fit in the predicted seventh instar confidence intervals after only four molts. The fact that some specimens do not fit in the "correct" size range suggests limitations in the method, but this is primarily due to the difficulty in rearing large numbers of scorpions past the early instars.

Only two adult males were available for comparison. In chela and metasoma V length both specimens fit the sixth instar confidence intervals. In carapace length one specimen is slightly smaller than predicted; the other is just within the lower limit for the sixth

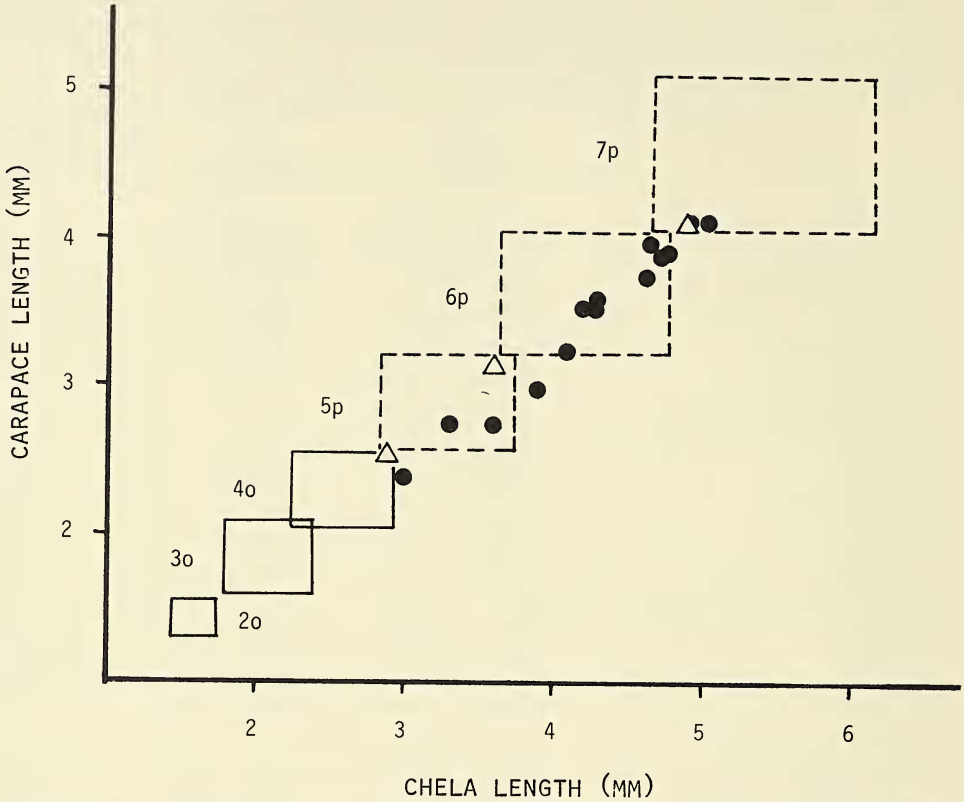

Fig. 1.—Plot of carapace length versus pedipalp chela length in instars of *Vaejovis bilineatus*. Boxes with solid lines depict 95% confidence intervals for instars observed (0) in the laboratory (2nd through 4th); boxes with broken lines depict 95% confidence intervals for predicted (p) instars (5th through 7th). Symbols are as follows: ∘ = field-collected specimens; △ = exuviae and specimen of female molting to maturity in the laboratory.

instar. This could be attributable to sexual allometry, but sample sizes of both field-collected adults and laboratory-reared specimens were too small to permit statistical analyses.

As stated previously there are potential problems with estimating size ranges of instars not observed. To minimize these problems, the estimations should be derived from large sample sizes of late instars, as this reduces error considerably. Another problem encountered in using this method is that of allometric growth at the maturation molt. This is common in scorpions (e.g., allometry in the metasomal segments in male *Centruroides* spp.), but with prior knowledge of its occurrence, adjustments can be made with reasonable accuracy (Sissom and Francke, unpublished data).

Data for instar duration obtained in the laboratory probably do not reflect durations in the field, as feeding regimes certainly differ. These data are reported here as they may prove useful in future laboratory studies.

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LITERATURE CITED

Francke, O. F. 1977. Obervations on the life history of *Uroctonus mordax* Thorell (Scorpionida, Vaejovidae). Bull. British Arachnol. Soc., 3(9):254-260.

Francke, O. F. 1979. Observations on the reproductive biology and life history of *Megacormus gertschi* Diaz (Scorpiones: Chactidae: Megacorminae). J. Arachnol., 7:223-230.

Francke, O. F. In press. Parturition in scorpions (Arachnida, Scorpiones): A review of the ideas. Rev. Arachnol.

Haradon, R. M. 1972. Birth behavior of the scorpion *Uroctonus mordax* Thorell (Vaejovidae). Ent. News, 83:218-221.

Hjelle, J. T. 1974. Observations on the birth and post-birth behavior of *Syntropis macrura* Kraepelin (Scorpionida: Vaejovidae). J. Arachnol., 1:221-227.

McAlister, W. H. 1960. Early growth rates in offspring from two broods of *Vejovis spinigerus* Wood. Texas J. Science, 4:162-168.

Polis, G. A. and R. D. Farley. 1979. Characteristics and environmental determinants of natality, growth and maturity in a natural population of the desert scorpion, *Paruroctonus mesaensis* (Scorpionida: Vaejovidae). J. Zool., London, 187:517-542.

Williams, S. C. 1969 Birth activities of some North American scorpions. Proc. California Acad. Sci., 37(1):1-24.

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